EFFECT OF PACING ON OPERATOR PERFORMANCE AND TASK DIFFICULTY

by

TARAKAM PEDDADA

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Major Professor

Dedicated to my cousin Smt. Turaga Lakshmi Prabhavathy, w/o Mr. P.V. Ramana. It is her love and inspiration that gives me the strength to achieve the goals, I need to. This is too little a gift to a lady with a loving heart and high moral values of life.

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I appreciate the help extended by my graduate colleagues in the collection of the data. Thanks are also to the subjects who have consented to participate in the experiment.

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Last but never the least are my parents whom I regard the most. Their love and perseverence are responsible for what I am today.

TARAKAM PEDDADA

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INTRODUCTION

The concept of "assembly line" which is commonplace in today's modern technology is attributed to Ford. It has played a major role in the industrial revolution and today, it is widely believed to be a necessity for mass production. Various subjective estimates suggest that worldwide, over 50 million people are working on machine paced tasks which include non-assembly line cases also (Salvendy, 1981). Caplan, et al as cited by Salvendy (1979) in studying 2010 men employed on 23 different jobs, concluded that "... the high levels of psychological strain and somatic complaints among persons on machine paced assembly lines suggests that attention ought to be directed toward improving their work conditions".

Stagner (1975) has reviewed much of the published research available in the area of machine pacing and concluded that "... the decisive component of the assembly-line task seems to be constraint, while repetitive stimulation is important, it is the line pace that prevents the individual from introducing variability by making irrelevant responses, changing pace or taking a break" (pp.40). He also indicates that "... the changes associated with aging seem to be in the direction of making personalities more compatible with assembly-line work" (pp.23) and concludes that more research is needed in this area to determine manpower needs.

Dudley (1958) as cited by Dudley (1962) has shown that when experienced workers in industry , engaged in repetitive tasks, are free to work at their own natural pace, their performance displays a highly consistent pattern, the principal feature of which is the absence of any trend in operation times throughout work periods. However, a large number of workers on repetitive work, are not free to work at their own pace but are subject to speed restrictions of various kinds. Speed restrictions could be due to a conveyor, machine, other worker, or the time allowed to complete their specified task. Eventually, various restrictions place a time restriction on the operator in completing the task. In the interests of a higher rate of output, the time in which an operation has to be performed tends to approximate the time required to perform the operation, that is, the time allowed for the task to be minimized.

In these conditions, Dudley (1961) says that "... experience leads us to anticipate a decrease in the quality of the work and the possibility of excessive operator fatigue. Such considerations have a considerable impact on production planning and on operative training, while all paced work constitutes a problem for those concerned with work measurement, particularly in the establishment of performance standards". In the light of all these it is definitely worthwhile to study more about the advantages and disadvantages of machine paced work vs self paced work.

Salvendy (1981) feels that, research must be aimed at a better understanding of human behavior rather than expanding research efforts that are aimed at comparing machine paced work with self paced work per se. He feels that based on this research, a development of work structures within organizations may be achieved which improves human behavior and performance. He feels that, by so doing, a theoretically sound basis for work design could be established, rather than attempting to accommodate human behavior and performance in the jobs. Though this approach seems to be a desirable one, it is very probable that it may take some time before any such new concepts can be practically implemented.

The two reasons for Salvendy's disapproval of comparing machine paced work and self paced work are, firstly, in real world work situations, machine-paced and self-paced work are frequently analogous to simplified and enlarged jobs, he feels that these two pacing conditions would be confounded with job content. Matching the job contents for the two pacing conditions in order to alleviate the confounding effect, he says, results in artificial work situations. Secondly, he feels that in a statistically balanced experimental design of experienced operatives, the prior experiences are confounded with pacing mode as the operators gained experience predominantly on only one pacing mode.

Though it is true that artificial situations have emerged, they are in most cases very much similar to the simplified jobs. There is certainly a distinct advantage in comparing machine paced work vs self paced work not only in aspects of performance and output but also analyzing the personality variables. Any significant interaction between performance and personality would help determine the compatibility of the individuals to the jobs.

Advantages and Disadvantages

The advantages of machine paced work include reduction in production costs due to specialization and reduction in material handling costs in the case of assembly line tasks. The primary disadvantages are that machine paced work does not provide psychological growth for the workers and also causes boredom and job dissatisfaction to the workers. The latter factor is of great importance as it might result in higher turnover, strikes for more pay etc.. It is not rare to find machine rates set at high speeds in the interests of higher productivity, thereby compromising product quality. Other disadvantages include not utilizing workers' maximal work capacity, and not being economically viable for volume production.

Classification Of Pacing

In the past various individuals as cited by Salvendy and Smith (1981) have defined various types of paced work and also classified them on different concepts. The various classifications are presented here under the names of the individuals responsible.

Murrell. Murrell (1963) classified paced work as being of two types, which he called as Type 1 pacing and Type 2 pacing. The type 1 form of pacing is the discrete system and the type 2 form of pacing is the continuous system as classified by Salvendy in machine-paced systems.

Buxley et al.. Buxley et al. identified the existence of pacing in three different environments, based upon product distribution. They are as follows.

Single-Model Lines: These are the lines in which only one single product is manufactured at any time.

Multi-Model Lines: These are the lines on which two or more similar types of models or products are processed separately in batches.

Mixed-Model Lines: These are the lines where two or more similar models or products are manufactured simultaneously.

Conway et al.. They further described a variation which combined elements of both paced and unpaced work. In this process the cycles are initiated by the operatives, but once the cycle is initiated, the operative is paced through a rapid sequence of motions.

Rohmert and Luczak. They have extended the concept of pacing to include information-processing tasks as well. The variation in these tasks is that the service time rather than being a single unit, could be partitioned into an information or decision component, and a motor component.

Salvendy (1981). He classified paced work under two major categories, namely, Human paced work and Machine paced work. He differentiated the various forms of human paced work by the demand they place on human behavior. On the other hand he identified the various forms of pacing that exist in machine paced work.

Human Paced Work. The various forms of human paced work as identified by Salvendy are as follows.

Truly Unpaced Work: In this form of pacing, the task is performed at a preferred and chosen pace by the operator.

Self-Paced Work: In this case the operator paces himself to achieve a goal, which is generally the management objective. This form of pacing occurs very often in jobs that are not paced by the machines. It is very rare that a truly unpaced form of job occurs in the industrial environment today.

Socially Paced Work: In this case the individual is paced by the peer or group pressure to perform at a set pace rather than by management goals or the machine.

Incentive Paced Work: In this concept the operator's output is directly related to his earnings. However, in most cases there is a minimum standard that must be met by the worker. Though this concept is widely used in simple repetitive jobs, it is losing ground as it is not seen to be working effectively.

Machine Paced Work. The following are the various concepts and attributes of machine paced work.

Length of Work Cycle: In all forms of machine paced work, the various restrictions ultimately control the length of the operator cycle time. The shorter the cycle time of operation, the less the operator variability is tolerated. Longer cycle times in machine paced work tolerate more operator variability and in some cases approach self-paced state. The experiment used in this study also paced the operator by controlling the length of the work cycle.

BufferStocks: Murrell (1963) defined buffer stock as " an arrangement which makes more than one component of feeding position available to an operative at the same time ". When machine paced work is operated with buffer stocks, the stringency associated with pacing is reduced and extremely large buffer stocks may reduce the system to a self-paced state. Some feel that the buffer stocks destroy the very purpose achieved by pacing, whereas some others feel it is a desirable concept as it can tolerate operator variability to a greater extent. However, more research needs to be conducted in this area before any valid inferences can be drawn.

Rate of Machine Paced Work: Machine paced work is is performed at rates ranging from 100 to 125 per cent where 100 per cent is defined as a "standard fair day's work". The work accomplished by a worker at his normal pace in an eight hour work-period is usually referred to as a "standard fair day's work". The impact of the work on the operator is higher at higher rates. There are also instances where the rate is lower than 100 per cent due to improper standards, imbalanced lines etc. thereby resulting in lower productivity.

Continuous vs Discrete Pacing: This is a very important distinction as the characteristics associated with each concept are quite different. An example of a continuous system would be an assembly or processes taking place on a continuously moving conveyor. In this case when analyzed from the operator's point of view, there are two factors that are of importance. Firstly, the machine rate i.e. the speed of the conveyor and whether the operator is able to complete the job at the same rate. Secondly, whether the tolerance allowed by the system tolerates the operator variability.

In the discrete system, the conveyor or other machine is stationery during a fixed job cycle when the operator is typically working on the job. In this case the cycle time and the tolerance time are not very distinct but are merged into a fixed job cycle. The tolerance in these systems is the time available to the operator when the machine is indexing, if the part can be accessed by the operator. In such cases the indexing period is also merged into the cycle time and as such there is no distinct period of tolerance. However, if the part cannot be accessed at all during the indexing period, there is no tolerance at all in the system.

Dainoff et al. (1981). In an attempt to put forth a systematic classification, they have proposed a two axes model that is more meaningful. They have chosen control over the initialization of the work cycle and control over the duration of the work cycle as the two orthogonal dimensions, as the paced work is manifested on these two dimensions. The extent to which the operator as opposed to the machine, has control over either or both of these dimensions could be reflected in the proposed four-quadrant classification scheme as shown in

Figure 1.

The tasks that fall in quadrant one (Q1) are those that are initiated by the machine, but the work cycle time is under the control of the operator. Such a task could be a telephone switch board operation in which case the arrival of calls is controlled by the machine whereas the duration of the call is controlled by the operator.

Quadrant three (Q3) tasks are initiated by the operator and the duration is controlled by the machine. On the other hand, the operator himself controls both the initiation and the duration in the case of quadrant three (Q2) tasks. These tasks (Q2 tasks) are generally referred to as unpaced tasks or self-paced tasks. In the case of quadrant four (Q4) tasks the machine (or the external environment) itself controls both the initiation and duration of the task. These tasks are generally referred to as machine paced tasks. Most of the previous research was directed at the Q2 and Q4 tasks including cross-quadrant comparison. Dainoff et al. suggest that there is need for more study in the Q1 and Q3 tasks. They further suggest that addition of a third dimension to the proposed two dimensional model would allow independant specification of job demand level within each quadrant.

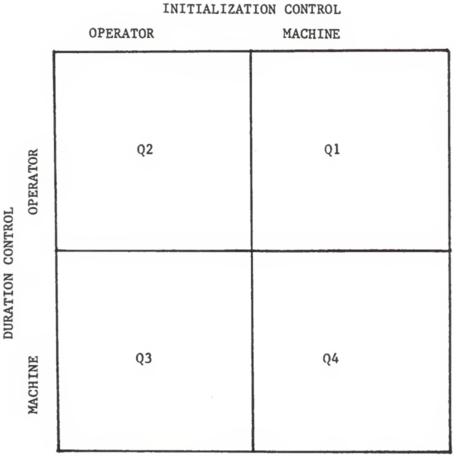


FIGURE 1. A Classification of Paced Work as Proposed by Dainoff et al. (1981).

Some Terminology Commonly Used in Pacing

Self Paced Work. The work conditions are said to be self paced when the operator paces himself in order to achieve a goal or meet a requirement, which in most cases is the goal set by the management. Thus the operator is not paced by the machine. This condition occurs in most of the industrial tasks which are not strictly paced by the machines.

Machine paced Work. In this case the operator is paced by the machine The level of pacing depends upon the rate of the machine. The rate of the machine is specified either by the cycle time available for processing or by the number of units passing per unit time.

Hits. These are the units that have been completely processed and in the right manner by the operator in the allowed cycle time.

Misses. These are the units that were not processed at all by the operator in the allowed cycle time.

Operator Cycle Time. This is the total time taken by the operator to process the unit after it arrived at the work station. This time is also referred as "service time" in some cases.

Machine Processing Time. This is the indexing time of the machine, or in other words, it is the time taken by the machine to position the next unit upon the completion of processing of a particular unit.

Machine Cycle Time. This term usually reffered to in machine paced conditions. " The time, the machine makes available for the operator to process a part " is called as the machine cycle time. The machine could be set at different rates, the cycle time being different for each rate. .

Tolerance Time. This particular period of time is not included in the available cycle time, but any processing being completed during this period results in a "Hit". The indexing period usually serves as a tolerance period in case of machine paced systems. The tolerance time could either be a proportion of the machine cycle time or a constant value at different machine rates. In this study, the task was such that the tolerance was available only during the indexing period. This time was held constant in all the conditions, however the subjects were not allowed to perform the task during this period.

Machine feed rate. The number of units being processed by the machine per unit time at that rate. The rate of work can be expressed either in terms of operator cycle time or as a feed rate of the machine.

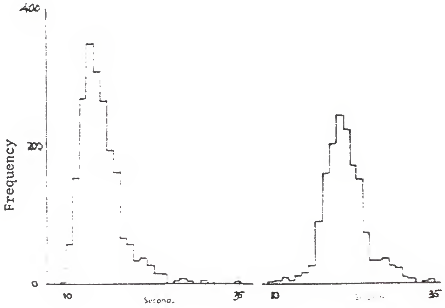
Effect of Operator Variability.

It is generally accepted that the operator being able to complete the task in the allotted time depends upon his or her variability. Murrell (1963) had defined "Certs", as those units that come up after a miss and as a result are not missed. This assumption is based upon the operator not being distracted from work for more than one cycle and also that the operator is present at the work station. Murrell says that certs are not at risk to the variability of the operator and thereby concludes that it is wrong to assume that all the cycles are at risk to the variability of the operator.

Murrell (1963) in his article states that when performance in paced and self-paced conditions are compared, the usual assumption of cycles completed in a time less than or equal to X1 (where X1 is the mean machine cycle time, at the machine rate 1) will be hits and those cycles that are >= X1 will be misses holds good only for discrete pacing systems. On the other hand, in the case of continuous systems, not only will all units completed in a time <= X1 be hits, but also a proportion of the cycle times between X1 and X1+X1*t (where "t" is the tolerance expressed as a proportion of the machine cycle time) will result in hits. He says that this proportion must be determined accurately before drawing any inferences. He has defined the output as those units completed in the allowed cycle time. But the completion of the task in the allowed cycle time does not necessarily mean that the part was processed correctly. Hence it is evident that he has neglected the quality aspect of the process which may be important. The setting of any particular pace depends upon the costs of rejects and reprocessing. Thus the considerations differ from situation to situation and hence pace setting cannot be generalized in a standard manner.

Effect of Learning

This section deals with the performance of an inexperienced operatives as opposed to an experienced one. Dudley (1963) found that the frequency distributions of cycle times of the inexperienced workers, working in unpaced condition, approximated a normal form. On the other hand, the distributions of experienced operatives showed a marked positive skewness. Figure 2 shows frequency distributions of cycle times in both the cases as plotted by Dudley in 1962. It can be seen that in both the cases, the range of cycle times is the same but the mean cycle time of the experienced operatives is shifted to a lesser value. Further the deviations about the mean are less in the case of experienced workers as compared to those of the inexperienced workers. From these observations, it can be inferred that at a given cycle time, the probability that the task will be completed is higher in the case of an experienced worker.



Cycle Time

Experienced Worker

Inexperienced Worker

Figure 2. Frequency distributions of experienced and inexperienced operatives as plotted by Dudley.

These findings are also in general agreement with the findings of Conrad (1955) and Murrell (1962). Murrell said that "this variability is a perfectly normal human characteristic and it cannot be prevented by an individual however hard he tries; it does not therefore necessarily reflect a change in the rate at which an individual is working and this fact must be recognized when any rating procedure is undertaken".

Dudley also found that, although the distribution of operation cycle times of trained and experienced operatives is positively skewed when workers are free to work at their preferred pace, there is a marked tendency for paced performances to yield a much more nearly normal distribution of operation times due to the effect of the mechanical restriction of a pacing system. These patterns must be observed carefully as these findings are applied to trained and experienced workers in the industry.

Previous Research

The various dependent variables studied in the past were

(1) Performance

(2) Productivity

(3) Psycho physiological effects

(4) Boredom

(5) Operator Variability

The various independent variables used in the studies were

(1) Machine feed rate

(2) Tolerance time

(3) Age of the workers

(4) Personality of the workers

(5) Rest periods

(6) Training and experience

Studies of Operator Performance. Murrell (1963) in studying the effects of feed rate and tolerance time on pacing concluded that

(1) With any tolerance, there is a limited range of machine rates for which optimum output is obtained and these rates will be different for different individuals.

(2) At any given rate, increasing the tolerance will increase the output to a limit which will be determined by the machine rate or the unpaced speed whichever is the least.

(3) Increasing the rate and tolerance in step together will increase the optimum output but may reduce the machine

utilization.

(4) Unless the tolerance is very large the rate of work will be below that which is normal in the self-paced condition.

(5) Maximum output can be obtained only when a proportion of misses is permitted.

(6) If virtually no misses are permitted the machine rate must be substantially below the self-paced rate.

(7) There are large individual differences between operatives.

Sury (1964) studied the effect of pacing and self-pacing on operator performance in a single stage production task. He supported Murrell's (1963) findings that in paced working it is necessary to set different feed rates for different operators in order to achieve maximum efficiency. His results showed that feed rate and tolerance time have a significant effect on operator output, misses, and delay, and that misses increase exponentially with increased feed rate. Murrell (1963) set tolerances as a constant proportion of the cycle time at each machine rate. On the other hand, Sury (1964) set absolute tolerance times for all the machine rates. Sury selected two tolerance periods of six seconds and three seconds, where the six second tolerance covered 99 to 99.7 per cent of all the operator's cycle times. His treatments were the various combinations of the two tolerance times and the four machine feed rates.

Sury (1964) suggested that feed rates must be set in the range of 10 to 15 per cent above the unpaced performance for near maximum successes at his minimum tolerance period. Further he states that a speed up effect can create a reduction in mean service time of eight to ten per cent at a feed rate in the region of ten per cent above mean unpaced performance in the case of a well motivated worker. He commented that setting tolerances as a proportion of cycle times would increase the severity of pacing and would result in optimality of successes being achieved at a lower feed rate. But it is probable that it may not be possible to maintain a fixed tolerance at all machine feed rates in all the systems. The concept of buffering is helpful in reducing the stringency of pacing but Sury seems to believe that the flexibility introduced by such stocks diminishes the motivation associated with pacing.

Franks and Sury (1966) studied the effect of feed rate and the position in the pick-up area (tolerance zone) in which a part is picked up during the service time. They also confirmed the findings of Sury (1964) that feed rate has a significant effect on operator performance and that misses increase with increased feed rates. They also found that in paced working at cycle times equivalent to mean unpaced performance and at +10 per cent of mean unpaced performance, the service time tended to decrease, the nearer the part was picked up towards the end of the zone, but the rate of decrease was reducing. On the other hand in paced working at cycle times equivalent to -10 per cent of mean unpaced performance, the service time tended to increase, the nearer the part was picked up towards the end of the zone. The rate of increase was found to be increasing. These findings confirm that tolerance when provided as a time or as a distance has a significant effect on the cycle time of the operator, and thereby on the output and hence must be optimized while designing a paced system.

Mcfarling and Heimstra as cited by Eskew and Riche (1982) studied the effects of machine-pacing vs self-pacing on performance and pleasantness of the task. The task was to detect flaws in 225 slides of printed circuits as the slides were projected on a screen. Half of the subjects were machine-paced through the task, which took about 52 minutes. The other half were allowed to pace themselves but were asked to try to finish it in 52 minutes. The results showed that not only the self-paced subjects detected more defects but also rated the task as less unpleasant than did the machine paced subjects.

Studies on Effect of Rest Periods. Murrell and Forsaith (1963) studied the effect of breaks on operator performance in repetitive work. They tested three hypotheses, namely,

(1) output would be higher and variability less if breaks were given at the end of an " Actile Period " (period of optimum performance) rather than at the point when the output decreased;

(2) the end of an actile period would be indicated by the onset of irregularities in performance which could be determined by the incidence of long cycle times in unpaced work and an increase in the number of missed cycles in paced work;

(3) the length of an actile period will depend upon the demand made by the job and the capacity of the worker to meet the demand (his/her actility).

The results of the data from two subjects recorded over a period of three and a half months indicated that the concept of actile period was valid but no definite conclusions could be drawn on machine paced work. They also came up with some tentative values for the length of the actile period. In the paced condition, the actile period was one hour as compared to 75 minutes in the unpaced condition. They also found that the better worker gave her best unpaced performance when rest was given after 75 minutes rather than after one hour. They also recorded fewer misses in the paced condition when three breaks were given than when working continuously. These findings certainly provide a good insight into the effects of rest pauses on productivity. Further research in an industrial environment with a more methodological approach controlling all the variables seems necessary, as suggested by them too.

__Studies on Psycho-Physiological Effects__. Corlett and Mahadeva (1970) studied the relationship between a freely chosen working pace and energy consumption and concluded that

(1) subjects performing repetitive submaximal physical tasks seem, when given the choice, to be able to choose the slowest pace which involves the minimum physiological energy cost per cycle as their working rhythm;

(2) the analysis of results failed to reveal any relationships of the "natural" pace with the subjects physical characteristics as age, height, weight, vital capacity, and body surface area.

Salvendy and Pilitsis (1971) found that the subjects within the 21 to 43 year age range render optimum human body efficiency around the freely chosen or natural rhythm of work region, whereas the subjects within the 45 to 64 year age range did not experience maximum human body efficiency within the freely chosen work region. However, when mean output per work minute during non-pacing was compared, it showed statistical significance, the value being higher for the 45 to 64 year age group.

Manenica as cited by Salvendy and Knight (1979) found that greater cardiac irregularity occurs during paced work than during unpaced work. Salvendy explains this finding as due to the operator's working rhythm being maintained externally by the machine in paced operations in which case the operator ought to pace himself in order to maintain a reasonable ouput and in the process imposing upon himself an extra amount of mental load, which could be the cause of greater arrhythmia suppression.

Sanders, Salvendy, and Knight (1979) found that the influence of age, personality, job satisfaction, and intelligence can derive a profile on paced and unpaced work. Thirty three subjects aged 28 to 64 years were studied, and their personality and attitudes were studied by administering several questionnaires. They concluded among other findings that workers are more satisfied during unpaced work rather than paced work not because they find unpaced work less boring or fatiguing but largely because of other variables associated with job structure. They identified personality characteristics that determine individuals who are more compatible to either or both types of pacing (Machine-paced and Self-paced). The characteristics and their correlation coefficients as reported by them are detailed in Table 1.

TABLE 1*

Correlation of Personality Characteristics with Pacing Conditions

MACHINE-PACED VS. SELF-PACED SCORES

Questionnaire/Variable	Mean	Standard Deviation	T-Value	Probability
Feeling Tone Checklist				
Unpaced	10.97	2.88		
Paced	11.29	2.46	-.58	.57
JDS/General Satisfaction				
Unpaced	8.91	1.72		
Paced	8.00	2.14	3.07	.00
JDS/Motivating Potential Score				
Unpaced	819.69	548.52		
Paced	452.63	411.79	-4.57	.00
PBQ/Boredom				
Unpaced	3.28	.78		
Paced	3.32	.86	-.27	.79
JDI/Work Satisfaction				
Unpaced	22.39	10.91		
Paced	19.12	10.19	2.33	.03
PSQ/Rate of Work Satisfaction				
Unpaced	4.22	1.00		
Paced	3.41	.78	-4.65	.00
PSQ/Autonomy Satisfaction				
Unpaced	13.45	7.46		
Paced	12.09	6.13	-2.53	.02
PSQ/Task Satisfaction				
Unpaced	22.45	4.76		
Paced	19.64	5.03	-2.59	.02

CHARACTERISTICS OF PEOPLE BEST SUITED FOR MACHINE-PACED AND SELF-PACED WORK

	Self-paced / Machine-Paced	Self-paced	Machine-paced
AGE	No statistically significant correlations	Older[5] (r = .33)	Older[4] (r = .40) Older[6] (r = .33) Older[7] (r = .32) Older[5] (r = .29, p = .052)
SATISFACTION	More Creativity[2] (r = .30) Creativity[2] (r = .30) Working Conditions[2,3] (r = .31, r = .34) Achievement[2,3,6] (r = .35, r = .31, r = .33) Activity[2,3] (r = .37, r = .46) Work[3] (r = .38) General Satisfaction[2] (r = .33)	Creativity[2] (r = .41) Independence[2] (r = .36) Variety[2] (r = .40) Ability Utilization[2,9] (r = .48, r = .34) Responsibility[2] (r = .41) Achievement[4] (r = .33) Activity[4] (r = .40) Work[3] (r = .32) Degree of Similarity[3,3] (r = .35, r = .34) General Satisfaction[2,9] (r = .41, r = .31)	Authority[3] (r = .37) Responsibility[3] (r = .30) Degree of Similarity[4] (r = .45)
PERSONALITY	Venturesome[1] (r = .36) More Intelligent[6] (r = .30) Emotionally Stable[1,7] (r = .32, r = .43) Humble[2,4] (r = .45, r = .39) Conscientious[1,6] (r = .48, r = .31) Trusting[7] (r = .34) Imaginative[3,7] (r = .40, r = .35) Forthright[3,7] (r = .44, r = .40) Conservative[3] (r = .35) Group dependent[4] (r = .36) Undisciplined[5] (r = .31) Introversion[2,4] (r = .37, r = .35) Stable[1] (r = .35)	Outgoing[6] (r = .32) Affected by Feeling[5] (r = .31) Humble[2,8] (r = .30, r = .31) Assertive[4] (r = .31) Conscientious[1,9] (r = .47, r = .32) Venturesome[1] (r = .34) Tough-minded[3] (r = .33) Shrewd[3] (r = .44) Forthright[4] (r = .31) Apprehensive[1] (r = .30) Controlled[9] (r = .35) Extroverted[4] (r = .37)	Outgoing[7] (r = .34) Less Intelligent[3] (r = .33) Affected by Feelings[7] (r = .35) Shrewd[7] (r = .41) Tense[2] (r = .34) Assertive[9] (r = .39)

[1] Pearson Feeling Tone Checklist
[2] JDS/General Satisfaction
[3] JDS/Motivating Potential Score
[4] PBQ/Boredom
[5] JDI/Work Satisfaction
[6] PSQ/Rate of Work Satisfaction
[7] PSQ/Autonomy Satisfaction
[8] PSQ/Task Satisfaction
[9] PCQ/Preference for Paced/Unpaced Work

*... Extracted from Attitudinal, Personality, and Age characteristics for machine-paced and self-paced operations by Sanders et al. (1979).

Wyatt et al. as cited by Stagner (1975) found that extroverted workers are more discontent due to monotony than introverted workers. They attributed this finding to the reason that many monotonous jobs have to be done under conditions preventing social interaction. Eysenck as cited by Stagner (1975), however, seems to believe that the real reason is, extroverts habituate more quickly and hence become bored more rapidly. In another interesting study, Kornhauser as reported by Stagner (1975) compared small town vs city workers; assembly line vs other blue collar jobs; and young vs older employees. He found that job dissatisfaction was the highest among young urban assemblers and lower in other groups. He also found that the group lowest on satisfaction was also the group that had the most anxiety, health complaints, worry about the future, insomnia, low self-esteem, depression, hurt feelings, hostility, and feelings of social isolation.

Locus of Control is a personality measure of an individual. This measure distinguishes the individual as either an internal or an external (an internal is defined as one who feels that he is in the control of his environment whereas an external does not feel so). The measure is based on Rotter's (1966) 23 item locus of control questionnaire. A lower score on the scale classifies the individual as an internal and a higher score as an external.

Sanders et al. have demonstrated that internals tend to make fewer errors on a vigilance task than do externals. Wolk and Ducette as cited by Eskew and Riche (1982) used the locus of control scale to assess the differences in what was referred to as "Perceptual Sensitivity" among individuals. The task was to detect errors in prose passages as they read, and also to try to remember in an incidental learning test at a later period. It was found that internals were superior in both paced and unpaced versions of the task, as they not only found more errors but also remembered more of the material later in the incidental learning test.

Eskew and Riche (1982) conducted a simulated inspection task requiring rapid visual scanning of electrical schematics to detect defects, in order to study the effects of machine-pacing vs self-pacing as related to locus of control. The task performed by the subjects was to detect defective circuits, in the slides that were projected on a screen. Subjects were run in pairs, one machine-paced and the other self-paced, but they watched the slides projected on the same screen. The self-paced subject had the capability to delay the slide only momentarily, whereas the machine-paced subject could not exercise this control. However, it appears that the delay if produced by the self-paced subject had the same effect on the machine-paced subject also. In such an event, the machine-paced subject was not strictly paced by the machine only but was also subject to the variability of the self-paced subject.

They found significant interaction of personality with the pacing variable. Their results also demonstrated that self-paced internals had higher criteria than self-paced externals, and thus made fewer false alarms; machine-paced internals had a lower criterion and thus made more false alarms than machine-paced externals.

Aims and Objectives of This Study

All the studies appear to have used production type of tasks but pacing may be equally important to inspection type of tasks as well in the industrial environment. This study attempts to study the effect of pacing on the operator performance, task difficulty, and the relationship between operator personality and his performance. Moreover, Murrell (1963) and Sury (1964) did not consider defectives, the units that were not processed correctly. It might be possible that the task chosen by them is of such nature that task completion essentially ensured that the unit was not a defective. But this need not be true in all cases, especially in the inspection type of tasks. This study takes into account the false alarms (the units that were processed incorrectly) made by the subject also. The previous studies in studying the psycho-physiological effects used several physiological indices like sinus arrhymia, heart rate, oxygen consumption, etc. but failed to record the feeling of the worker himself. Though the studies gave very valuable information, the personal feeling of the worker if recorded can explain the worker's actions more clearly than any other index. In this study the subject's feeling was recorded by his opinion on the difficulty of the task on the Borg's perceived exertion scale (see Figure 3) and his preference of the conditions that he would like to work in. In studying the personality variable, the subject was administered the 23 item personality questionnaire (Rotter, 1956) that distinguished them as either internals or externals.

The task used in this study was a "pennies inspection task. The subjects had to inspect the pennies and mark them as either defectives or non-defectives. The variables defined below were used as the dependant variables in the study.

If A= total number of pennies in a treatment(constant, 800);
B= number of pennies actually inspected;
C= number of pennies correctly marked, or hits;
D= number of pennies wrongly marked, or false alarms;
E= (A-B), number of pennies not marked, or misses;
then, Good production+= C/A;
Good performance= C/B;
Good production rate= C/time taken to inspect "B" pennies;

The good production and the good production rate have been normalized to a maximum of one.

7	Very very easy
8	
9	Very easy
10	
11	Fairly easy
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very very hard
20	
21	

FIGURE 3. Borg's Relative Perceived Exertion Scale

PROBLEM

The objective of this study is to investigate the effects of paced vs self-paced environment on

(1) The good production of the operator;

(2) The good performance of the operator;

(3) The rate of good production of the operator;

(3) The subjective evaluation of the operator of the task difficulty; and

(4) The relationship between the operator's personality and (a) good production, (b) subjective evaluation.

The following directional hypotheses were made in the study.

(1) The good production of the operator would be optimum at a rate slightly higher than his/her mean self-paced rate (viz. 110 per cent).

(2) The self-paced condition is expected to result in the best performance of the operator.

(3) The good production rate is expected to be maximum at a rate significantly higher than his/her mean self-paced rate (viz. 120 per cent).

(4) The task difficulty is expected to be lowest in the self-paced condition.

(5) Internals are expected to perform better in the self-paced condition and externals in the machine-paced conditions.

METHOD

Procedure

The task used in this study was a " Pennies Inspection task ". There were six conditions that were applied to each subject in the experiment. One was the self-paced condition and the other five were machine-paced rates ranging from 90 per cent to 130 per cent of the subject's mean self-paced rate, at equal intervals of 10 percentage points. The objective in choosing speeds up to 130 per cent was to study the effects at rates higher than 115 per cent. Earlier studies of Buffa (1961), Sury (1964), etc. limited the rates to 115 per cent.

Task

The task essentially to be performed by the subject was to inspect the penny units at the work station and mark the pennies as either good or defective. The units were pieces of cardboard of size 37.5X22.5 centimeters which had 40 pennies glued to them in a 4X10 rectangular array. Some of the pennies were defectives (marred with a chisel). The defectives were distributed randomly over each unit. The number of defective units on each board ranged from none to nine pennies. Each unit was covered with a transparent cellophane sheet on which the subject could mark with a marker provided to him. When the units arrived at the work station they had a white sheet of paper covered over them to eliminate operator visibility during the indexing period. The work station was situated on a variable speed belt conveyor. The conveyor indexed at the end of the cycle time to bring the next unit into position. The conveyor indexed at a speed of 0.667 feet per second at all times. However, the subject was not allowed to perform the task while the conveyor indexed. The conveyor would come into a stationery mode when the unit was exactly in position at the work station due to a photoelectric sensing device.

In the self-paced condition the operator had control over the arrival of the units. He was asked to press the red button near his left hand as soon as he completed inspecting the unit at the workplace. This response of his, activated the clock and also indexed the conveyor. In the machine-paced conditions, a time delay that was set by the experimenter determined the time that the subject had to inspect the units in that condition. The subject was asked to press the button in the machine-paced conditions also in order to retain the consistency of the task. In case he was done earlier, his response gave the experimenter the actual time taken by him to inspect the unit regardless of the set delay. The subject was idle until the conveyor indexed and brought the next unit into position.

The paced conditions applied to each subject were based on his mean cycle time in the self-paced rate. Hence the absolute values of the cycle times applied in each condition varied from subject to subject. The experimental conditions applied to each subject and the procedure in which they were chosen are detailed in Table 2. The time delay set for each unit in the machine-paced rates was equal to the calculated cycle time for the particular paced rate.

The units marked by the subject were re-examined by the experimenter and the number of hits, misses, and false alarms were recorded. The complete experiment lasted for about two hours. The duration of each treatment was approximately 15 minutes. The duration varied depending upon the cycle time of each treatment.

Learning

The subject was allowed a 20 minute learning period, during which period he could not only familiarize himself with the task but also gain skill in performing the task. The learning period was divided into four intervals of five minutes each. During the first interval, he was asked to perform the task at his self-paced rate and his cycle times were recorded. During the other three periods, he was machine-paced at 100 per cent, 110 per cent, and 120 per cent respectively of his mean cycle time in the self-paced condition. This familiarized the subjects to working at different rates. The order of application helped the subjects in gaining more skill in performing the task.

TABLE 2

Details of Various Conditions Studied.

Condition	Details
Self-Paced (SP)	The subject had complete control over the arrival rate.
Paced Rate 90% (PR 90)	The subject was paced by the machine at 90 per cent of his mean SP rate.
Paced Rate 100% (PR 100)	The subject was paced by the machine at 100 per cent of his mean SP rate.
Paced Rate 110% (PR 110)	The subject was paced by the machine at 110 per cent of his mean SP rate.
Paced Rate 120% (PR 120)	The subject was paced by the machine at 120 per cent of his mean SP rate.
Paced Rate 130% (PR 130)	The subject was paced by the machine at 130 per cent of his mean SP rate.

Calibration

After the learning period the subject was asked to perform again in the self-paced condition. The cycle times obtained in this condition were used to calculate the subject's mean cycle time, based upon which his paced rates were calculated. The subject had to inspect 20 units, which were the same as inspected by him in each of the treatments.

At the end of the calibration period, the six treatment conditions, one self-paced and five machine-paced, were applied to the subject. Prior to the application of the treatments the subject was asked to answer Rotter's internal-external locus of control questionnaire. Administering the questionnaire at that instant not only provided the subject a short rest period but also gave the experimenter some time to perform the necessary calculations.

Instructions and Informed Consent. The detailed instructions given to the subject prior to the start of the experiment appear in Figure 4. The format of informed consent signed by the subjects is shown in Figure 5.

Order of Application and Randomization. The six treatments were applied to each subject in a randomized sequence.

INSTRUCTIONS

You are about to participate in an experiment that tests the effects of pacing on operator performance. You will have to perform the "pennies inspection task" under various pacing conditions. You are to perform the task as fast as you can without sacrificing accuracy. You will have 20 minutes to familiarize yourself with the task and also gain enough practice in performing the task.

TASK

Penny boards will arrive at the specified workstation on the conveyor. You are to wait until the conveyor comes to a stop before you start performing the task. This instant is represented by the red light in front of you not glowing. You are to lift the white cover on the board and start inspecting the pennies. Some pennies are defective (defectives are those which are either defaced, or have drilled holes or chisel scars on them) while some are good. As you inspect, you are to mark the good pennies with a check mark (✓) and the defective pennies with a cross (X) mark, with the marker supplied to you. Each penny board is a unit and the time taken to inspect each unit is recorded. There are two different types of conditions that can signify the completion of the task or the allowed time for the unit. The two types of conditions are: (1) self-paced conditions. On this condition you have to press the red button provided to you as soon as you complete inspection of the unit. This response will activate the conveyor and bring the next unit into position.

(2) paced condition. In this condition, the unit will arrive at a rate set by me. You will be allowed only a certain time for the inspection of a unit, and at the end of the allowed period of time, the next unit

will come into position. It is possible that, in some cases, you will complete inspecting the unit before the end of the allowed time, while in other cases the allowed period of time is not sufficient. In case you finish the task earlier, you are to press the red button signifying your completion of the task and wait for the arrival of the next unit. In the other case, where you cannot complete the unit by the end of the allowed time, you are to press the button as soon as the conveyor starts moving.

At no time can you perform the task while the conveyor is moving; i.e., when the red lamp in front of you is glowing. During the initial period of 20 minutes, you are to mark the pennies with the blunt end of the marker. After the initial familiarization period, you will have six conditions - one self-paced and five paced. At the end of each condition, you are to rate the difficulty of the task on the Borg's Perceived Exertion Scale supplied to you. Later, you are to identify the condition that you most prefer and also state the reasons in a sentence or two for your preference. At the end of the experiment you are to answer a questionnaire supplied to you.

You can clear any doubts with me at any time during the experiment. There is no danger or risk involved in the experiment and the data recorded by me is strictly confidential. You are free to leave the experiment at any time but I naturally prefer that you complete it so I can get all the data needed.

Your participation in the study is very much appreciated.

Figure 4. Detailed Instructions Given to the Subjects

INFORMED CONSENT

I have read the instructions of the experiment carefully and I do hereby fully agree to participate in the experiment.

____
Signature

____
Date

Figure 5. Informed Consent Signed by the Subject

Experimental Design. The design was a completely randomized block design and all the conditions were applied to each subject. This controlled for the effects of individual differences in the data. The experimental design is shown in Figure 6.

Independent Variables

There were two independent variables in the study. One was self-paced and the other was machine-pace rate with five levels.

Dependant Variables

The various responses of the subject recorded were

(1) time taken to complete inspection of each unit;

(2) the number of hits on each unit;

(3) the number of misses on each unit;

(4) the number of false alarms (the pennies that were wrongly identified);

(5) the subjective rating of the difficulty of the task on the Borg's perceived exertion scale;

(6) subjective evaluation of the conditions and the preference of the subject of either self-paced or machine-paced conditions.

(7) personality of the subject (score on the internal/external scale).

SUBJECT # INTERNAL/EXTERNAL SCORE SEX

AGE HEIGHT WEIGHT

CONDITION RESPONSE	PR 90	PR 100	PR 110	PR 120	PR 130	SELF_PACED
HITS						
MISSES						
FALSE ALARMS						
RPE						
MEAN CYCLE TIME						
STANDARD DEVIATION						

FIGURE 6. EXPERIMENTAL DESIGN.

The above responses of the subject were transformed into good production, good performance, and good production rate. The subjective ratings on the relative perceived exertion scale of Borg indicated the task difficulty.

Subjects and Recruitment Procedures

An incidental sample of fifteen subjects was recruited from a junior level management class. All the subjects received extra course credit for participating in the experiment.

Apparatus and Materials

The apparatus for the experiment mainly constituted of a belt conveyor, penny boards, and an electronic circuit specially built for the experiment. The circuit was provided with the capabilities to

(1) set the type of pacing (self-paced or machine paced);

(2) set the delay in machine-paced conditions; and

(3) an LED display of the time taken by the subject to inspect the unit, accurate to one-tenth of a second.

The circuit used a photo-electric sensing device to activate the clock. The earlier of the two responses, either of the subject (press of a button) or end of the set delay clocked the time.

RESULTS

Laboratory experiments often suffer from the shortcoming that the subjects are not experienced workers. However, this study used a task that was very simple and in addition enough time was provided for learning. The mean of the standard deviations of cycle times before learning was 2.0197. This value when compared against 1.1587 (same measure after learning) gives evidence that subjects were well experienced before any data was collected.

Analysis of variance and Duncan's test were performed on the data to test for the significance of the treatments. The four dependent variables were good production, good performance, good production rate, and Relative Perceived Exertion ratings. The data was analysed as a randomized complete block design with subjects as blocks. The Treatment by Subject interaction mean square was used as the error term in all tests for significance.

The Good Production

The results of the analysis of variance and Duncan's test are presented in Table 3 and Table 4 respectively. It was found that treatment had a significant effect. The self-paced condition was not different from 90 per cent and 100 per cent rates.

TABLE 3

Analysis of Variance of Good production

Source	DF	Sum of Squares	Mean Square	F-Value	PR>F
Model	89	0.778678	0.00875	99999.9	0.0
Error	0	0.0	0.0		
Corrected Total	89	0.778678			

Source	DF	ANOVA SS	F-Value	PR ≥ F
Treatment	5	0.44797	.	.
Subject	14	0.142902	.	.
Treatment*Sub	70	0.1878	.	.

Test of hypotheses using the ANOVA MS for Treatment*Sub as an Error term

Source	DF	ANOVA SS	F Value	PR ≥ F
Treatment	5	0.44797	33.39	0.0001

TABLE 4

Duncan's Multiple Range Test for Good production

Alpha= 0.05   DF= 70   MS Error= 0.0026829

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	Treatment
A	0.99758	15	SP
A	0.99658	15	PR 90
B A	0.98275	15	PR 100
B	0.94842	15	PR 110
C	0.88442	15	PR 120
D	0.80408	15	PR 130

The 110 per cent rate was not different from 100 per cent either. The other higher rates were different from each other and these lower rates.

The Good performance

The ANOVA summary and Duncan's test are detailed in Table 5 and Table 6 respectively. The result did not show any significant differences among the treatments. As may be seen in Table 6 the mean performances of the treatments are almost identical.

The Good production rate

The results of the analysis of variance and Duncan's test are presented in Table 7 and Table 8 respectively. It was found that treatment has a significant effect. The self-paced condition was not different from the 90 per cent rate. Neither were 120 per cent and 130 per cent rates significantly different. The 110 per cent rate was seen to be significantly different from 130 per cent rate but not different from 120 per cent rate.

Relative Perceived Exertion Rating

The ANOVA summary and details of Duncan's test are presented in Table 9 and Table 10 respectively. The treatment was found to be highly significant. Self-paced condition was not significantly different from the 90 per cent rate.

TABLE 5

Analysis of Variance of Good performance

Source	DF	Sum of Squares	Mean Square	F-Value	PR>F
Model	89	0.00052646	0.00000592	99999.9	0.0
Error	0	0.0	0.0		
Corrected Total	89	0.00052646			

Source	DF	ANOVA SS	F-Value	PR ≥ F
Treatment	5	0.00001426	.	.
Subject	14	0.00036118	.	.
Treatment*Sub	70	0.00015102	.	.

Test of hypotheses using the ANOVA MS for Treatment*Sub as an Error term

Source	DF	ANOVA SS	F Value	PR ≥ F
Treatment	5	0.00001426	1.32	0.2642

TABLE 6

Duncan's Multiple Range Test for Good performance

Alpha= 0.05 DF= 70 MS Error= 2.2 E-06

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	Treatment
A	0.99883	15	PR 90
A	0.99871	15	PR 100
A	0.99824	15	PR 120
A	0.99798	15	PR 110
A	0.99797	15	PR 130
A	0.99775	15	SP

TABLE 7

Analysis of Variance of Good production rate

Source	DF	Sum of Squares	Mean Square	F-Value	PR>F
Model	89	16.928344	0.190206	99999.9	0.0
Error	0	0.0	0.0		
Corrected Total	89	16.928344			

Source	DF	ANOVA SS	F-Value	PR ≥ F
Treatment	5	1.172819	.	.
Subject	14	14.376702	.	.
Treatment*Sub	70	1.378824	.	.

Test of hypotheses using the ANOVA MS for Treatment*Sub as an Error term

Source	DF	ANOVA SS	F Value	PR ≥ F
Treatment	5	1.172819	11.91	0.0001

TABLE 8

Duncan's Multiple Range Test for Good production rate

Alpha= 0.05 DF= 70 MS Error= 0.0196975

Means with the same letter are not significantly different.

Duncan Grouping			Mean	N	Treatment
		A	2.6096	15	PR 130
	B	A	2.5379	15	PR 120
	B	C	2.4491	15	PR 110
D		C	2.3603	15	PR 100
D			2.3187	15	PR 90
D			2.3008	15	SP

1... Means expressed as number of pennies per second.

TABLE 9

Analysis of Variance of RPE ratings

Source	DF	Sum of Squares	Mean Square	F-Value	PR>F
Model	89	1016.500	11.42135	99999.9	0.0
Error	0	0.0	0.0		
Corrected Total	89	1016.500			

Source	DF	ANOVA SS	F-Value	PR > F
Treatment	5	580.900	.	.
Subject	14	254.667	.	.
Treatment*Sub	70	180.933	.	.

Test of hypotheses using the ANOVA MS for Treatment*Sub as an Error term

Source	DF	ANOVA SS	F Value	PR > F
Treatment	5	580.900	44.95	0.0001

TABLE 10

Duncan's Multiple Range Test for RPE ratings

Alpha= 0.05   DF= 70   MS Error= 2.58476

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	Treatment
A	17.000	15	PR 130
B	15.400	15	PR 120
C	14.000	15	PR 110
D	12.067	15	PR 100
E	10.0667	15	PR 90
E	9.867	15	SP

All the other treatments showed significant differences.

Correlation Analysis

The internal/external score correlated with the good production, RPE ratings, and rate of good production in the 100 per cent paced rate. The correlations obtained were -0.12204, -0.23252, and -0.04179 respectively. None of the correlations were significant at 0.05 alpha level.

The following two ratios were designed to show the contrast between the two types (self-paced and Machine-paced) of pacing.

Ratio (RPE)= RPE of SP/ Mean of (RPE of PR 120, RPE of PR 130)

Ratio (Good production)= Good production in SP/ Mean of (Good production in PR 120, Good production in PR 130)

The observations of the two higher rates were only used in calculating the ratios. This was because the data did not show much variation among the lower rates. The correlation between Internal/external score and Ratio (Good production) was 0.29569. The correlation between the score and the Ratio (RPE) was 0.01796. Neither of the two correlations were significant.

DISCUSSION

The results highlight the fact that the rate of pacing has a significant effect on the good production, good production rate, and also contributes to the difficulty of the task.

Good production

It was found that the good production was maximum in the self-paced condition and machine-paced rates of 100 per cent or lower. The 120 per cent and 130 per cent rates indicate a considerable drop in good production. Figure 7 shows the plot of good production vs rate of pacing. It is parabolic in nature. The variation beyond 110 per cent rate is relatively higher than at lower rates.

Good performance

This variable measures the performance of the subject in the pennies actually inspected by him. Hence this directly tests the effect of pacing on the quality of the work completed by him. Insignificance of this variable shows that the pace of work has no effect on the quality of work. Thus, it can be said that false alarms are negligible in this simple inspection task.

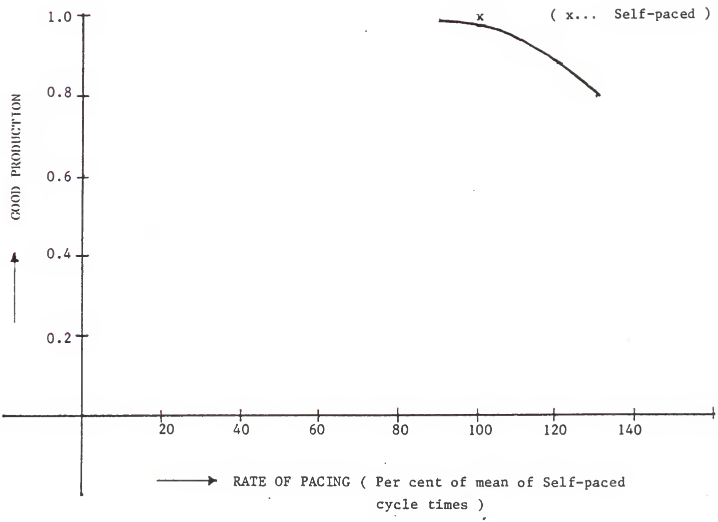


FIGURE 7. Plot of Good Production vs Rate of Pacing.

Good production rate

In an industry, the management may be more concerned about production per unit time rather than total production as such. The results suggest that greater good production rate can be obtained at rates as high as 120 per cent and 130 per cent. This result is not in agreement with the findings of Sury (1964) who found that "machine feed rates must be set at 10 to 15 per cent above the mean self-paced speed in order to achieve near maximum successes". It must be realized that Sury's experiment did not study speeds beyond 115 per cent. Figure 8 shows the plot of good production rate vs rate of pacing. It is linear in nature indicating that rate of good production increases with an increase in the rate of pacing. However, the linearity will not hold at some rates beyond 130 per cent, as a worker's physical capacity is reached. When once that state is reached, any increase in the rate would result in decreasing the rate of good production. The insignificance between 120 per cent and 130 per cent rates probably suggests that speeds beyond 130 per cent do not result in a higher rate of good production.

These results are limited by the fact that the duration of work in each treatment was only 15 minutes, though the subject worked continuously for two hours at various rates. On the other hand, Sury's (1964) experiment experiment lasted about four hours.

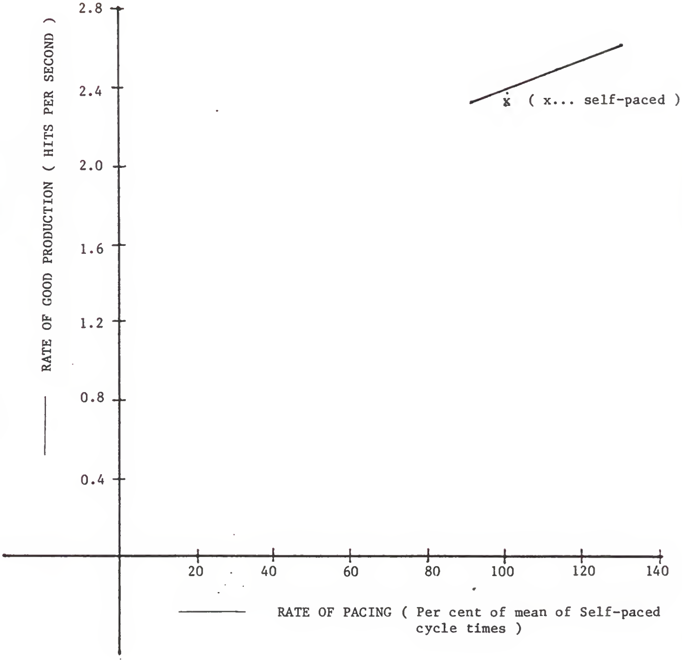


FIGURE 8. Plot of Good Production Rate vs Rate of Pacing

A study involving fairly long duration of work and validating these results is essential before any definite conclusions can drawn.

Relative Perceived Exertion Rating

The means of subjective evaluations of the subjects on the Borg's relative perceived exertion scale show that the self-paced condition is relatively easier than machine-paced speeds of 100 per cent or above. The means (see TABLE 10) indicate that task difficulty increases with increased levels of pacing.The 110 per cent rate has a mean of 14.0 which is between " Somewhat Hard " and " Hard " on the Borg scale. This probably is the right level at which tasks must be set. This condition does not differ significantly with the 120 per cent rate in the rate of good production. Hence it might be a right level of pacing for tasks that demand reasonably normal output and quality.

Figure 9 shows the relationship between RPE rating and the rate of work. It is also linear in nature indicating that increased levels of pacing result in greater task difficulty.

Significant differences were observed between self-paced condition and the 100 per cent rate. The mean cycle time of 100 per cent rate was the mean of the cycle times in the self-paced condition.

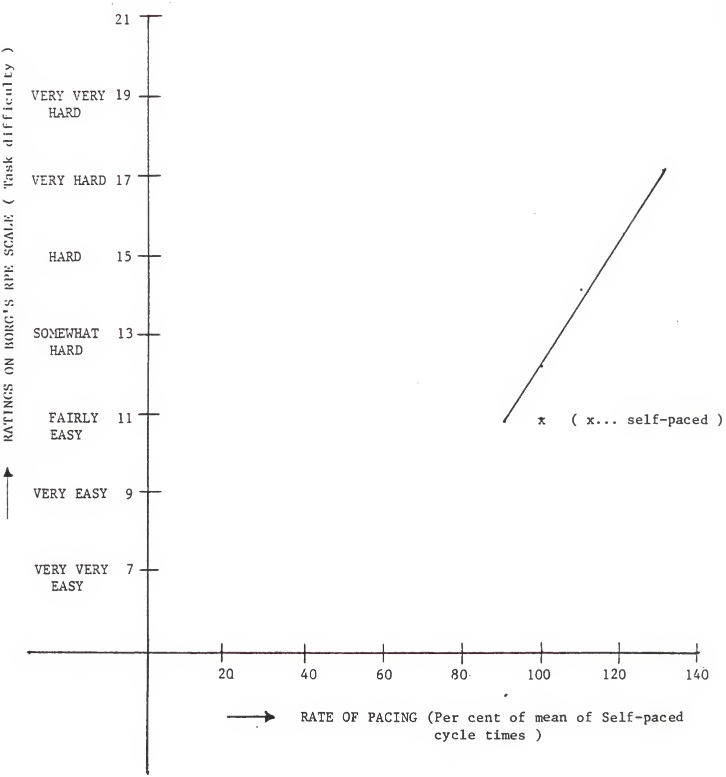


FIGURE 9. Plot of Task Difficulty vs Rate of Pacing.

This result suggests that psychological satisfaction (due to having the control) and tolerance of variability, both of which are absent in 100 per cent rate influenced the subjective evaluations of the subject. These two factors were probably responsible for the subjects rating the self-paced condition as "very easy".

Correlation Analysis

The relatively low correlation figures obtained suggest that there is no relationship between locus of control and the type of pacing in which the operator performs better. Further 14 of the 15 subjects preferred to work in self-paced conditions. This result disproved the hypothesis that internals perform better in self-paced conditions and externals in machine-paced conditions. Hence the findings of Eskew and Riche (1982) are not validated. There are two possible reasons for the differences in findings. Firstly, the machine-paced subjects in their experiment were not strictly machine-paced but were subject to the variability introduced by the self-paced subjects. Secondly, subjects did not perform under both conditions and if they did, the results might have been different.

Practical Considerations

The main objective of studies of this nature is to determine the right level of pacing that results in maximum productivity. Unfortunately, the results cannot be directly applied as the considerations vary widely from situation to situation. One important factor to be considered is quality.

The results of this study indicate that self-paced conditions or machine-paced speeds lower than the mean self-paced speed must be preferred in situations that do not tolerate misses. This result is in agreement with that of Sury (1964) who found that "if virtually no misses are permitted, the machine rate should be significantly lower than the mean self-paced speed". However, if misses can be tolerated higher rates are advisable in the interests of greater productivity. An interesting finding was that the quality is not effected by the rate of pacing. The variable, good production suggests self-paced condition or lower machine rates. On the other hand, the variable, good production rate suggests higher machine rates. The latter variable incorporates the effect of time taken for completing the task too. The higher rates would take less time but result in greater number of misses. Hence the basic tradeoff is between the cost of misses and reprocessing and the cost of time (primarily labor cost and also the costs of overheads, utilities etc.). However, in simple tasks such as this the costs of misses and reprocessing are negligible and hence higher rates may be more profitable. It should also be realized that higher speeds result in increased task difficulty. This may not be desirable as it results in greater worker dissatisfaction thereby increasing the factors like turnover, absenteeism etc..

The right approach in determining the correct level of pacing is to perform an economic analysis of the various possible alternatives in the situation. The factors of primary importance are

(1) the costs of misses and reprocessing;

(2) task difficulty;

(3) performance;

(4) output per unit time;

(5) worker satisfaction.

The factors like task difficulty, worker satisfaction do not have any direct monetary value associated with them. This might seem to be a setback in performing an economic analysis. However, approximate costs can be picked up from the monetary losses due to absenteeism, turnover, strikes etc..

The subjects' comments indicated that the reasons for their dislike towards machine-paced work were largely that

(1) quality of work may suffer;

(2) the feeling of not being able to complete the work in the allowed cycle time.

Hence when machine-paced conditions, especially the higher rates are set, it is good to let the workers know the considerations adopted by the management to the workers. Such an act may probably alter the psychology of the workers.

The results of laboratory experiments fail to apply in industry in some cases as the motivation of the workers differs widely in the two situations. Considering the fact that all the subjects in this study were fairly well motivated, these results apply to situations where there is good worker motivation and good understanding between the management and the employees.

Implications for Future Research

There is not much published research available in this area, though most tasks in the industry are paced. Studies with a methodological approach and probably in practical situations seem to be very essential. Research must be aimed at determining the range of speeds that result in higher productivity and worker satisfaction. More needs to be studied about the characteristics of self-pacing and how productivity can be improved in this condition.The effects of tolerance and variability need careful attention. Firstly, a more consistent definition of tolerance seems to be necessary.

The results of this study are valid only to tasks of similar nature and that have about the same levels of complexity, worker motivation, etc.. Hence it is difficult to identify the set of tasks to which results apply. A desirable approach is to prepare an inventory of all attributes of various tasks. Each attribute could have a fixed scale (say 1 to 10). In such a case, every task can be associated with a numeric value based on the levels of its attributes, on similar lines as MTM. In such an event the results can be generalized to all tasks of the same level (that have the same numeric value).

The findings of Murrell (1963) have provided a good insight into the effect of rest pauses. But further study is necessary to determine accurately the number of pauses and the duration of each pause. A survey involving workers from different types of jobs regarding the preference of number and duration of breaks could be interesting.

A variable that was not studied is task complexity. The rate of work resulting in optimum productivity varies with complexity of the task. An experiment studying the effect of pacing on tasks of different complexities could be very informative.

The personality variables need to be studied in greater detail in the light of significant findings by Sanders et al. (1979). Any encouraging results in this area would aid in matching the worker to the appropriate job, thereby increasing worker satisfaction.

CONCLUSIONS

(1) Self-paced conditions and machine-paced rates of 100 per cent or less result in optimum good production.

(2) Machine-paced speeds significantly higher than 100 per cent (viz. 120 per cent and 130 per cent) are suitable for maximum rate of good production.

(3) Rate of pacing does not effect the quality of the work in simple tasks of this kind.

(4) Task difficulty increases linearly with increases in the rate of pacing.

(5) Performance of an operator or the task difficulty judged by him in a type of pacing does not depend upon his locus of control.

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APPENDIX A

RAW DATA

OBS	SUB[1]	SCORE[2]	SEX	TIME[3]	TRT[4]	RPE[5]	MISS[6]	FA[7]
1	1	6	M	330	1	11	0	0
2	1	6	M	316	2	10	2	0
3	1	6	M	292	3	15	2	0
4	1	6	M	264	4	17	12	0
5	1	6	M	232	5	19	105	0
6	1	6	M	330	6	8	1	0
7	2	6	F	304	1	13	1	0
8	2	6	F	284	2	15	29	1
9	2	6	F	260	3	15	116	2
10	2	6	F	228	4	17	248	2
11	2	6	F	202	5	18	332	1
12	2	6	F	346	6	7	0	2
13	3	13	M	286	1	10	0	0
14	3	13	M	288	2	12	5	0
15	3	13	M	266	3	13	13	0
16	3	13	M	238	4	13	119	0
17	3	13	M	210	5	15	175	0
18	3	13	M	290	6	9	0	0
19	4	13	F	376	1	11	6	0
20	4	13	F	342	2	9	23	0
21	4	13	F	312	3	15	73	1
22	4	13	F	278	4	18	140	0
23	4	13	F	246	5	19	212	1
24	4	13	F	368	6	9	0	2
25	5	5	M	524	1	9	0	1
26	5	5	M	490	2	9	0	0
27	5	5	M	466	3	11	0	0
28	5	5	M	418	4	12	0	1
29	5	5	M	368	5	13	0	1
30	5	5	M	456	6	7	0	0
31	6	11	F	460	1	9	0	2
32	6	11	F	486	2	12	34	3
33	6	11	F	432	3	11	1	6
34	6	11	F	392	4	16	38	3
35	6	11	F	342	5	14	126	2
36	6	11	F	532	6	10	0	9
37	7	6	M	372	1	12	0	1
38	7	6	M	380	2	15	0	1
39	7	6	M	368	3	16	15	0
40	7	6	M	324	4	16	4	0
41	7	6	M	290	5	18	61	1
42	7	6	M	360	6	14	0	0
43	8	8	F	374	1	7	0	5
44	8	8	F	392	2	11	31	3
45	8	8	F	354	3	11	47	0
46	8	8	F	313	4	13	21	0
47	8	8	F	278	5	15	131	2
48	8	8	F	384	6	7	0	4
49	9	14	M	296	1	12	0	0
50	9	14	M	262	2	10	0	0
51	9	14	M	252	3	14	104	1
52	9	14	M	224	4	13	137	1
53	9	14	M	196	5	13	149	1
54	9	14	M	298	6	9	0	0
55	10	14	F	368	1	9	0	1
56	10	14	F	352	2	11	21	0

RAW DATA

OBS	SUB	SCORE	SEX	TIME	TRT	RPE	MISS	FA
57	10	14	F	324	3	13	35	1
58	10	14	F	290	4	15	120	1
59	10	14	F	254	5	19	241	0
60	10	14	F	386	6	9	0	0
61	11	8	F	322	1	9	0	0
62	11	8	F	344	2	13	11	2
63	11	8	F	312	3	15	28	2
64	11	8	F	282	4	17	97	1
65	11	8	F	248	5	19	146	1
66	11	8	F	350	6	11	0	1
67	12	5	M	338	1	10	0	0
68	12	5	M	344	2	13	3	0
69	12	5	M	300	3	16	0	0
70	12	5	M	280	4	17	0	1
71	12	5	M	250	5	20	20	1
72	12	5	M	324	6	15	0	0
73	13	14	F	380	1	11	0	1
74	13	14	F	372	2	11	11	0
75	13	14	F	346	3	13	83	1
76	13	14	F	306	4	13	173	1
77	13	14	F	268	5	15	194	1
78	13	14	F	392	6	9	0	0
79	14	10	M	344	1	16	20	2
80	14	10	M	310	2	18	22	5
81	14	10	M	288	3	15	29	7
82	14	10	M	256	4	16	116	6
83	14	10	M	226	5	19	223	5
84	14	10	M	310	6	13	0	7
85	15	4	F	250	1	11	0	1
86	15	4	F	236	2	12	0	0
87	15	4	F	226	3	17	50	2
88	15	4	F	198	4	18	144	1
89	15	4	F	174	5	19	217	2
90	15	4	F	248	6	11	1	2

1 ... Subject #

2 ... Internal/External Score

3 ... Time taken to inspect 20 units (penny boards)

4 ... Treatment
- 1.. 90 per cent rate
- 2.. 100 per cent rate
- 3.. 110 per cent rate
- 4.. 120 per cent rate
- 5.. 130 per cent rate
- 6.. self-paced condition

5 ... Borg's Relative Perceived Exertion Ratings

6 ... Number of pennies missed in the treatment

7 ... Number of False alarms in the treatment

EFFECT OF PACING ON OPERATOR PERFORMANCE AND TASK DIFFICULTY

by

TARAKAM PEDDADA

B.E. (Mechanical Engineering), Osmania University, India

AN ABSTRACT OF A MASTER'S THESIS

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Manhattan, Kansas

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ABSTRACT

The main objective of the study was to investigate the effects of pacing on worker performance and task difficulty in a simple inspection task. One self-paced condition and five machine-paced conditions were tested in the study. The latter five conditions ranged from 90 percent to 130 percent (at equal intervals of 10 percentage points) of the subject's mean cycle time in the self-paced condition.

Fifteen subjects from a senior level management class participated in the study. The task performed by them was a pennies inspection task. They had to mark the pennies as either defective or non-defective. The responses recorded were the quantity of good production and the time taken to complete them. The subjects also evaluated the difficulty of the task on a relative perceived exertion scale.

The results indicated that good production is high in self-paced conditions and machine-paced speeds lower than 100 percent. But the rate of good production was significantly high at machine-paced speeds of 120 percent and 130 percent. The rate of pacing did not effect quality of the work. Task difficulty increased with increases in the rate of pacing.